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ABSTRACT

The history of the Educational Testing Service (ETS) Factor Kits is summarized. The original ETS Factor Kit was developed in 1954 and contained 51 items, three each for each of 15 factors and six for a 16th factor. The next edition was developed in 1963 and included adaptations (clones) of the defining tests instead of the exact copies. These tests marked 24 factors. The current edition of the ETS Factor Kit was developed in 1976 and consists of 72 tests marking 23 cognitive factors. Some limitations of paper-and-pencil versions of the kits are identified, and computer-administered versions being developed are described. Information is given about a study comparing computer and paper-and-pencil tests. The Factor Kit tests were intended to be used as markers in factor-analytic studies of cognition and have been widely used in psychological research. Tests that could be used to determine a number of major factors were assembled in "kits" for factorial research. Limitations of the format restricted the kinds of cognitive processes that could be assessed and the ways in which tests could be scored. Questions of test misuse arose. Creating computer-administered versions posed a number of problems in the areas of timing, confirmation and correction of responses, and pacing. For the computer administered versions, system features are described. A small pilot study compared the two formats using data for 30 secondary school students aged 13 to 19 years, who took part of each kit of 10 tests in each format. Results suggest that the factors measured by these 10 tests were not affected by the use of the computer version. Versions of the computer-administered kit for field testing are anticipated in 1992. Three tables provide details about the 1954, 1963, and 1976 editions of the Factor Kits. A 17-item list of references is included. (SLD)

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COMPUTER-BASED ASSESSMENT OF COGNITION: THE ETS FACTOR KIT

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Educational Testing Service

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COMPUTER-BASED ASSESSMENT OF COGNITION: THE ETS FACTOR KIT

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For more than 35 years the ETS Factor Kits (French, 1954; French, Ekstrom & Price, 1963; Ekstrom, French & Harman, 1976) have provided researchers with tests of cognitive processes such as reasoning, memory, verbal ability, and spatial ability. The Kit tests were intended to be used as markers in factor-analytic studies of cognition.

The Kit tests are widely used in psychological research. According to the Social Sciences Citation Index there have been over 400 published studies citing the Kits from 1972 through 1988. Recent studies include the factor structure of the ASVAB battery (Augustin, Gillet, Guerrero & Curran, 1989); verbal and visual learning styles (Kirby, Moore & Schofield, 1988); hemispheric differences in components of mental rotation (Fischer & Pellegrino, 1988); performance on competing tasks (Fogarty & Stankov, 1988); familial resemblances in cognitive abilities (Abdelrahim, Nagoshi, Johnson & Vandenberg, 1988); reasoning and language proficiency (Boyle, 1987); the effects of cognitive training on mental-ability structure (Schaie, Willis, Hertzog & Schulenberg, 1987); and video-game performance (Jones, Dunlap & Bilodeau, 1986).

This paper summarizes the history of the Kits; identifies some limitations of the paper-and-pencil editions; describes the computer-administered version of the Kit, now being developed at ETS; and presents information about a small study comparing computer-administered and paper-and-pencil tests.

History of the Kits

At the beginning of the 1950s, factor analysis was seen as an emerging technology with the potential to achieve order out of the hodgepodge of aptitude and achievement tests then available. To that end John W. French produced a monograph, The Description of Aptitude and Achievement Tests in Terms of Rotated Factors, "devoted to the progress of test development toward the situation where the test constructor has a file of tests to measure each factor of the mind" (French, 1951, page v). This monograph featured re-interpretation of factors and their identification across studies. Its wide acceptance led French to the idea of putting together, in a "Kit", several tests that could be expected to determine a number of major factors.

The Original Kit. The first Kit, entitled the Kit of Selected Tests for Reference Aptitude and Achievement Factors (French, 1954) was published in 1954. It consisted of 51 tests,

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three for each of 15 factors and six for a sixteenth factor. (A list of the factors and tests in this Kit appears in Table 1.) For each test, a name and a symbol, linking the test to a factor, were provided. A manual provided a description of each test, a key, information about time limits and appropriate grade levels, and information about how to obtain a copies of the test or the requirements for reproducing it. (The authors of all of these tests had agreed they could be reproduced for research purposes.) The manual did not provide reliability, validity or norming information stating that this was not appropriate since the tests were "suggested for the single purpose of factorial research." Kit users were asked to provide French with information from research studies so it could be shared.

A Kit with "Clones". By 1958 it became apparent that a revised Kit was needed. New research, especially work of Guilford in the area of divergent production, had identified additional factors. Other factors needed re-conceptualization or different marker tests. It also had become apparent that some abuses of the Kit were occurring, usually involving unauthorized reproduction of the tests without the copyright owner's permission. It was decided that the new Kit would use adaptations or "clones" of the defining tests, whenever the copyright owners agreed, instead of exact copies. The adaptations made it possible to give the new Kit tests a relatively uniform format and directions that were as parallel as possible. The adaptation also involved producing two separately timed parallel parts, both for administrative convenience and to facilitate the estimation of test reliability. Blanket permission for reproduction was given to the adapted tests created at ETS and for tests copyrighted by J.P. Guilford; tests copyrighted by Sheridan Supply Company had to be purchased from that source. Small scale studies were done to obtain correlation matrices to see if the new adapted tests for a factor held together but, because of financial limitations, no factor analysis of the entire set of tests was undertaken. A list of the factors and tests in the 1963 Kit of Reference Tests for Cognitive Factors (French, Ekstrom and Price) appears in Table 2.

The Current Kit. By 1971 it became apparent, once again, that it was time to revise the Kit. A review of the literature suggested that at least six additional factors were sufficiently well-established to warrant inclusion in a new Kit (Ekstrom, 1973). "Established" was defined as a factor having appeared in at least three different studies done by at least two different researchers or research laboratories. Carroll's "Psychometric tests as cognitive tasks: A new `Structure of Intellect'", also informed the work; it was published as one of the technical reports from the revision project (Carroll, 1974). This revision involved more experimental work and field tryouts of the tests than had been done earlier (Ekstrom, French & Harman, 1979). Because of persistent problems with the unauthorized reproduction

of the Kit tests a process of licensing test use was instituted. The 1976 edition of the Kit (Ekstrom, French & Harman, 1976) consisted of 72 tests marking 23 cognitive factors (See Table 3).

Problems and Limitations

The paper-and-pencil format of the earlier editions of the ETS Factor Kit restricted the kinds of cognitive processes that could be assessed. It also made it impossible to separate speed and level-of-accuracy (Carroll, 1988). For the researcher, the paper-and-pencil format meant that hand scoring of responses was necessary and that the results then had to be entered into a data base for analysis.

A second limitation has been that no factor-analysis has been conducted using the entire set of tests in any Kit. Consequently, the relationship between the factors has been inferred from limited data. A recent study (Wothke et al, 1990) included all factors in the 1976 Kit but the design, using only two tests for each factor, led to an underestimate of the number of factors. (Defining a factor by two nearly identical tests will, typically, lead to approximately one-third to one-fourth too few factors with roots greater than one.)

An on-going concern has been the extent to which the adapted tests are adequate stand-ins for the original research instruments. The development of the "clone" tests relied on the construct validity of the factors and on the editors' knowledge of cognition. One study of the tests for five spatial factors (Ekstrom, 1967) concluded that most of the tests in the 1963 Kit were similar enough to the originals in the 1954 Kit to load on the same factor. An exception was the Hidden Figures Test, created by Witkin and his colleagues to measure field dependence-independence and included in the 1963 Kit as a marker for flexibility of closure; this test appears to be primarily a measure of visualization, although it does have some variance on flexibility of closure. A recent re-analysis of this study by Carroll (personal communication) shows similar results. Other re-analyses by Carroll, using a hierarchical methodology, show that some of the tests in the 1954 Kit are more factorially complex than was originally thought.

Finally, there has been concern over the use of the Kit tests in ways never intended by the authors. The Kits were created to facilitate research in cognition by factor-analytic methods. The Kit tests were selected because they had been used in previous factor-analytic studies, were short and easy to administer, and the authors were willing to have them reproduced for research use or adapted. These tests were never considered by the Kit editors to be the best or defining measures of these aspects of cognition; they are merely the ones that met the Kit requirements. As was pointed out in the manual for the 1976 Kit,

"There are probably no such things as truly "pure" factors." (Ekstrom, French and Harman, 1976, p. 4). Despite this and other caveats, there has been an increased use of Kit tests in a variety of studies including, in addition to psychological research, neurological, physiological, and genetic research. It may be appropriate to use Kit tests to identify the kinds of cognitive processes affected by head injuries or exposure to toxics. It is less clear that the Kit tests should be used to "prove" the relationship between hormonal levels and certain abilities or to demonstrate that certain components of cognition have a hereditary component. In addition, there has been concern that the Kit has provided a consensus about abilities significant for research (Cronbach, 1984), thus tending to limit rather than stimulate factor-analytic studies of cognition.

At the 1952 conference, which lead to the creation of the first Kit, a number of points were made that are important to remember today. Dorothy Adkins voiced concern that continued use of the same tests to define a factor might lead to the perpetuation of mistakes. Harold Bechtoldt commented that "'best test' is a poor concept; a test merely measures." French pointed out that the tests being considered for the Kit were not ideal and that, because their selection was heavily influenced by considerations about brevity and availability to ETS, their use should be limited to research (French, 1952).

All of this points out the need for more research with the Kit tests, both to understand more about the constructs called "cognitive factors" and to further our understanding of cognitive processes. To this end, ETS is developing a new computer-administered version of the Kit.

Creating a Computer-Administered Kit

There were three basic problems involved in creating computer-administered versions of the Kit tests: 1) How to change test format without changing the required cognitive processes; 2) How to keep the tests as similar as possible to the paper-and-pencil versions while, at the same time, making use of the advantages of computer administration; and 3) How to design the new Kit to facilitate research that will add to our understanding of cognitive processes, especially the relative contributions of speed and power.

Among the issues that have been considered are those involving timing, confirmation and correction of responses and pacing.

Timing Issues. Although most computer-administered tests have chosen not to limit testing or response time, we decided to do so. We reasoned that, since there are time limits on paper-and-pencil tests, removing time restrictions entirely might

change subjects' response strategies and alter the meaning of the results. We have not established a time limit for an entire test but we have limited the time for each item. The default response time has been set high enough, however, to allow subjects to ponder over some of the more difficult items. Researchers will have, for each item, a record of response latency as well as response correctness. The preliminary computer-administered version allows researchers to determine time for the initial response and, in addition, time for changing and/or confirming responses. We are have decided to include timing switches that can be set by the researcher to increase data collection flexibility and to allow a variety of approaches to the analysis of response time.

Confirmation and Response Correction Issues. Although the norm in cognitive experiments on computers seems to be to require no confirmation of responses, computerized psychometric instruments typically require such confirmation to allow subjects to change their answers. Since one goal was to make our computer-administered tests as much like the paper-and-pencil originals as possible, we decided to require confirmation of responses and to permit changing answers on all but the most highly speeded tests.

Pacing Issues. Another question was whether to allow subjects to pace themselves and regulate the speed at which new items appear or to have the pace of administration controlled by the computer. Again, the with goal of keeping the computer-administered tests as much like paper-and-pencil tests as possible, we decided to have the items self-paced on all but the most highly speeded tests. On the speeded tests, subjects will be alerted before item presentation by a "beep" and, as indicated above, no confirmation or changing of responses will be involved.

With these issues in mind, we moved to the design of the system.

System Features. The minimum system configuration for the new computer-administered Kit is an IBM-compatible computer with 256k of memory, a graphics adaptor, and two floppy disks. Thus a relatively inexpensive computer can be used. In a networking environment, several students can be tested simultaneously.

The computer not only records subjects' responses for each item but also provides scoring for most tests, thus doing away with the antiquated hand scoring process. In addition, a data base will be created enabling researchers to go directly from data collection to data analysis without the necessity of manually entering the responses into a computer.

The program also includes features that will allow the researcher to assign different tests to different subjects and to

vary the order of testing from subject to subject. With some additional programming by the researcher, it will be possible to decide on the basis of previous tests, which test should be administered next. The feature of having two parallel and separately timed parts for each test facilitates pre-post studies, such as changes in cognitive processes as a result of an intervening experience.

System Components. The major components of the system are the Test Delivery System, the Kit Tests, the Test Administration System, and the Permanent Database Facility. The relationship among these is shown in Figure 1.

The Test Administration System (TAS) is the program through which the researcher designs and monitors the testing. This system prepares the files needed by the Test Delivery System. These files are: 1) ID.CRD - the list of subjects and the test administration design to which each has been assigned; 2) DESIGNxx.CRD - one or more files containing data collection designs (the last two characters of the file name uniquely identify the design); 3) PATHS.CARD - containing the location of certain files; and 4) LICENSE.CRD - which will count the number of tests processed by the system. The researcher can query the Test Administration System to determine the status of subjects and the remaining number of licensed copies of each test. Once the tests have been administered through the Test Delivery System, the Test Administration system collects data from the response files and converts them to an ASCII file in preparation for transferring the data to the Permanent Database Facility.

The Test Administration system contains a separate program for each test. This was done because, in the Factor Kit, test stimuli, responses and scoring differ so much from one test to another that it would have been difficult to devise a sufficiently general program and item bank to handle all of the tests. Despite the fact that there is a separate program for each test, the flow of information is essentially identical. However, the item banks differ across tests as do the response and scoring modules. While there is a separate executable program for each test, a single file (RESP.CRD) is use to hold the responses from all of the tests.

The Test Delivery System (TDS) interacts with the subject. Once the researcher has designed the data collection, a proctor can test a subject simply by running the batch file TDSBAT.BAT. This batch file, in turn, runs three programs: 1) VIDEO, which loads the appropriate graphic drivers for the computer; 2) TDS itself, which "plays" the lines in the DESIGNxx.CRD; and 3)VIDEOFF, which unloads the graphic drivers. TDS asks each subject for identification number and proceeds if this is correct. TDS does not administer the tests but, rather, runs the programs called for by DESIGNxx.CRD which do the actual

administration. Thus, DESIGNxx.CRD is a script of programs that are to be "played". These programs need not all be Kit tests. Other tests can be included or training programs can be presented between pre- and post-tests. As a rule, the script implicit in DESIGNxx.CRD is static; that is, all tests and the order they will be given in is fixed. However, dynamic data collection systems are possible by having an external test or program modify the DESIGNxx.CRD.

The Permanent Database Facility will manage the storage of data and create data matrices for analysis.

Flexible Timing, Confirmation and Pacing Models. Computer administration provides not only the possibility of recording response time but, also, the advantage of flexibility in administration design. As indicated earlier, we used this advantage to solve the question of which of several timing, confirmation and pacing models to choose. A researcher can choose one of four models; confirmation with or without pacing and no confirmation with or without pacing. In regard to timing, we decided to record all keystrokes, from initial to final, and to make it possible for researchers who are interested in only a sub-set of these response elements to select those of concern.

Comparability

Our work with the Kit provides an opportunity to study how format change affects a very diverse group of tests. In the summer of 1989 Scott Hershberger, a pre-doctoral summer fellow at ETS, conducted a small pilot study of ten Kit tests in both paper-and-pencil and computer-administered format.

The tests were measures of the induction, general reasoning, and verbal comprehension factors. All of these tests are in multiple-choice format. Time limits applied to the pencil-and-paper mode but the computer administration was untimed. The subjects were 30 secondary school students, ages 13 to 19. Testing order was counter-balanced by format but not by factor. The tests were always administered in the same order. Group 1 took Part 1 of each test by computer, directly followed by Part 2 in paper-and-pencil format; Group 2 took Part 1 in the paper-and-pencil format and Part 2 by computer.

The results strongly suggest that the factors measured by these ten tests are not affected by the use of computer-administered tests. Due to the small sample size, Hotelling's T^2 test of group differences could not be used. Therefore, multiple t-tests were conducted between Groups 1 and 2 for each part of each test, with the Bonferroni correction to control the family-wise error rate. Uniformly, no significant mean differences were found based on mode of administration.

This study also explored whether the difficulties of individual items changed across the two modes of administration. In order to compare the relative difficulty of each of the items in each format on the ten tests, the difficulty of each item on each test was computed. Each of the item difficulties was transformed into a delta by multiplying the difficulty index's normal curve equivalent by 4 and then adding 13. For each of the two parts of each test, deltas computed from the scores of Group 1 were correlated with deltas computed from the scores of Group 2. In no case was the correlation between deltas below .61 and, most commonly, the correlations were above .80. These results are all the more surprising when one considers that the paper-and-pencil tests might have been more difficult because of the time limits imposed on the subjects.

The subjects were also asked which test administration mode they preferred. Without exception, every examinee voiced a preference for the computer-administered format. Many of the subjects from it easier to respond on the computer and felt their performance would be correspondingly better. However, despite this perception, neither subjects' mean level of performance nor individual item difficulties varied significantly between the two formats.

Availability

Information about the 1976 Factor Kit (paper-and-pencil) is available from: E. Mingo, Educational Testing Service 05-R, Princeton, NY 08541. A complete Kit, containing all 72 tests and a manual, can be purchased for $30.00. Licensing agreements for the use of specific tests are also available at 10 cents per copy reproduced, with a minimum charge of $50. ($35. for graduate students).

We anticipate having portions of the computer-administered Kit available for field-testing in 1991. Individuals interested in the computer-administered Kit or participating in the field test should contact: R. Ekstrom, Educational Testing Service 09-R, Princeton, NY 08541.

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Table 1

Content of the 1954 Kit of Selected Tests for Reference Aptitude and Achievement Factors

Factor	Tests	Author(s)
Aiming	Dotting	Adapted from MacQuarrie
	Tracing Easy	" " "
	Tracing Difficult	" " "
Flexibility of Closure	Concealed Figures	Thurstone (Adaptation of Gottschaldt Figures)
	Designs	Thurstone
	Copying	Thurstone (Adaptation of test by MacQuarrie)
Speed of Closure	Gestalt Completion	Thurstone (Adaptation of Street Gestalt)
	Mutilated Words	Thurstone
	Four-Letter Words	Thurstone
Deduction	False Premises	Thurstone
	Reasoning	Thurstone
	Word Squares	Adkins and Lyerly
Induction	Letter Grouping	Thurstone
	Marks	Thurstone
	Raven Progressive Matrices	
Ideational Fluency	Topics	Adapted by Taylor from Cattell
	Theme	Adapted by Taylor from Cattell
	Things	Adapted by Taylor from Cattell
Associative Memory	Picture-Number	Adapted from a test by Anastasi
	Word-Number	Thurstone
	First Names	Thurstone
Mechanical Knowledge	Tool Information	Guilford-Zimmerman
	Automotive Info.	" "
	Mechanical Info.	" "
Motor Speed	Writing X's	
	Writing "lack"	
	Writing digits	
Number Facility	Addition	
	Division	
	Subtraction and Multiplication	
General Reasoning	Mathematical Aptit.	ACE Psychological Exam.
	General Reasoning	Guilford-Zimmerman
	Ship Destination	Christensen & Guilford
Spatial Relations and Orientation	Cards	Thurstone
	Cubes	Thurstone
	Spatial Orientation	Guilford-Zimmerman

Speed of Symbol Discrimination	Letter "A"	Thurstone
	First Digit Cancellation	Thurstone
	Scattered X's	Thurstone
Verbal Knowledge	Vocabulary	Adapted from a test by Carroll
	Vocabulary	Adapted from Cooperative Vocab. Test
	Wide Range Vocabulary Test	" " "
	Advanced Vocabulary	" " "
	Advanced Vocabulary	Adapted from a test by Carroll
	Advanced Vocabulary	Thurstone
Visualization	Form Board	Thurstone
	Punched Holes	Thurstone
	Surface Development	Thurstone
Word Fluency	Suffixes	Thurstone
	Prefixes	Thurstone
	First and Last Letters	Thurstone

Table 2

Factors in the Kit of Reference Tests
for Cognitive Factors (1963)

Flexibility of Closure
Speed of Closure
Associational Fluency *
Expressional Fluency *
Ideational Fluency
Word Fluency
Induction
Length Estimation *
Associative (Rote) Memory
Mechanical Knowledge
Memory Span *
Number Facility
Originality *
Perceptual Speed [1]
General Reasoning
Semantic Redefinition *
Syllogistic Reasoning [2]
Spatial Orientation [3]
Sensitivity to Problems *
Spatial Scanning *
Verbal Comprehension [4]
Visualization
Figural Adaptive Flexibility *
Semantic Spontaneous Flexibility *

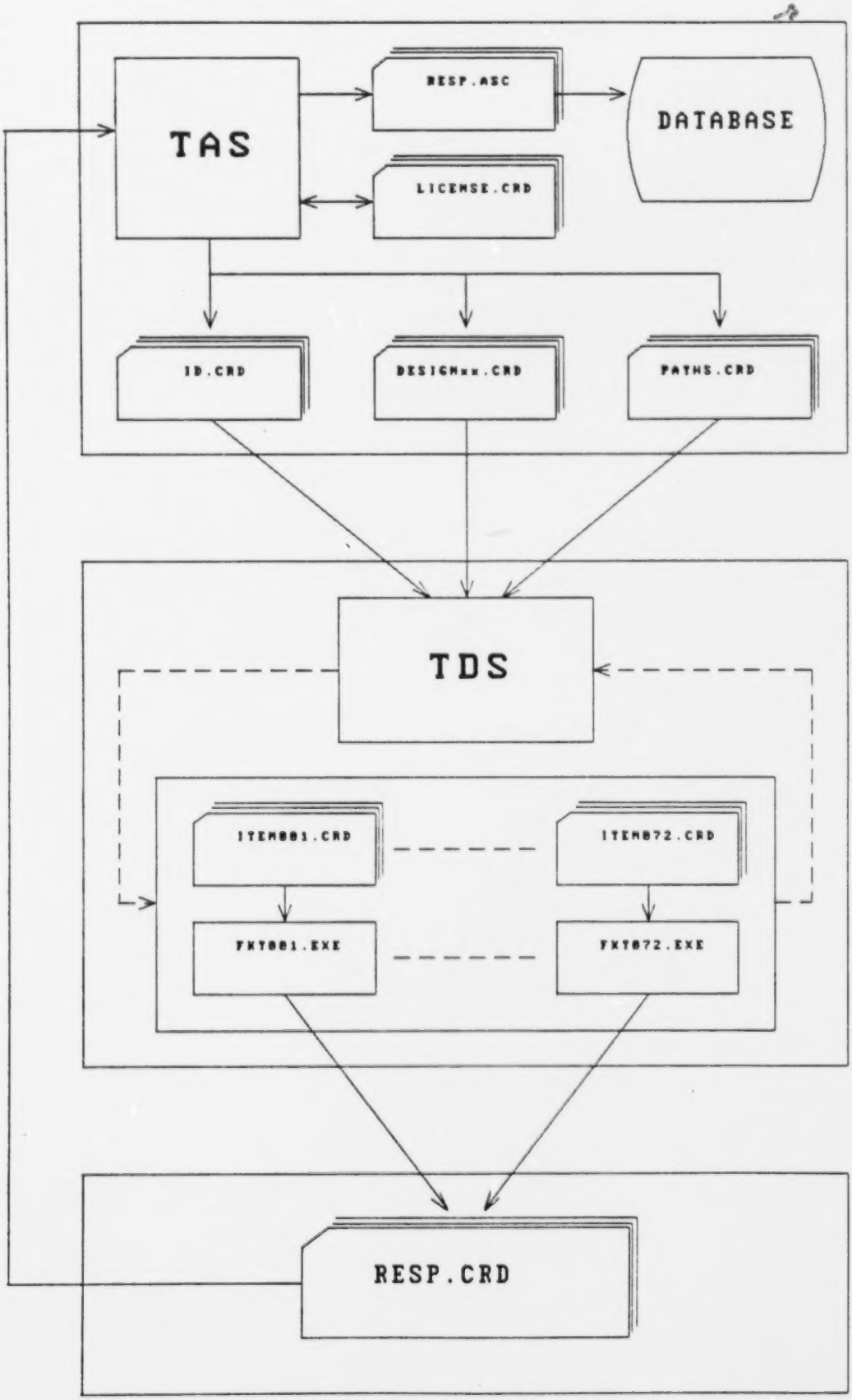
* = New factor since 1954 Kit
1 = Called speed of symbol discrimination in 1954 Kit
2 = Called deduction in 1954 Kit
3 = Called spatial relations and orientation in 1954 Kit
4 = Called verbal knowledge in 1954 Kit

Table 3

Factors in the 1976 Kit of
Factor-Referenced Cognitive Tests

Flexibility of Closure [1]
Speed of Closure [1,2]
Verbal Closure [3]
Adaptive Flexibility [2]
Expressional Fluency [2]
Figural Fluency [3]
Ideational Fluency
Word Fluency [2]
Induction
Integrative Process [3]
Associative Memory
Memory Span
Visual Memory [3]
Number Facility [2]
Perceptual Speed [2]
General Reasoning [1]
Logical Reasoning [2,4]
Spatial Orientation [1]
Spatial Scanning
Verbal Comprehension
Visualization
Figural Flexibility [2,4]
Flexibility of Use [3]

1 = Modified test(s)
2 = New test(s)
3 = New factor and new tests
4 = Factor name changed/modified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RESP.ASC
DATABASE
LICENSE.CRD
ID.CRD
DESIGNxx.CRD
PATHS.CRD
TDS
ITEM881.CRD
ITEM872.CRD
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